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**APPENDIX K**

**Preliminary Results of Radiation Measurements on EURECA**

**by**

**E.V. Benton and A.L. Frank**

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PRELIMINARY RESULTS OF RADIATION MEASUREMENTS ON EURECA\*

E.V. Benton and A.L. Frank  
Physics Research Laboratory  
University of San Francisco  
San Francisco, CA 94117-1080, U.S.A.

ABSTRACT

The eleven-month duration of the EURECA mission allows long-term radiation effects to be studied similarly to those of the Long Duration Exposure Facility (LDEF). Basic data can be generated for projections to crew doses and electronic and computer reliability on spacecraft missions. A radiation experiment has been designed for EURECA which uses passive integrating detectors to measure average radiation levels. The components include a Trackscope, which employs fourteen plastic nuclear track detector (PNTD) stacks to measure the angular dependence of high LET ( $\geq 6$  keV/ $\mu\text{m}$ ) radiation. Also included are TLDs for total absorbed doses, thermal/resonance neutron detectors (TRNDs) for low energy neutron fluences and a thick PNTD stack for depth dependence measurements. LET spectra are derived from the PNTD measurements.

Preliminary TLD results from seven levels within the detector array show that integrated doses inside the flight canister varied from  $18.8 \pm 0.6$  cGy to  $38.9 \pm 1.2$  cGy. The TLDs oriented toward the least shielded direction averaged 53% higher in dose than those oriented away from the least shielded direction (minimum shielding toward the least shielded direction varied from 1.13 to 7.9 g/cm<sup>2</sup>, Al equivalent). The maximum dose rate on EURECA (1.16 mGy/day) was 37% of the maximum measured on LDEF and dose rates at all depths were less than measured on LDEF. The shielding external to the flight canister covered a greater solid angle about the canister than in the LDEF experiments.

INTRODUCTION

The EURECA mission provided the opportunity for measurements of the space radiation environment in low earth orbit (LEO) over an extended period (11 months). Compared with the LDEF mission, the time period was 16% as long, but the number of orbits was sufficient to obtain an excellent average over the LEO radiation

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field. In orientation EURECA was in stable alignment with the sun, rather than Earth, which complicates the shielding distribution about the experiments. However, calculations based on environmental radiation models can be made by averaging over shielding for comparisons with the measurements.

A selection of passive integrating radiation detectors has been flown on the EURECA mission in a sealed aluminum canister. This experiment is similar to the A0015 and P0006 experiments which were flown on LDEF. The EURECA experiment included plastic nuclear track detectors (PNTDs), TLDs and thermal/resonance neutron detectors (TRNDs) to measure total absorbed doses, high LET particle fluences, directionality and shielding depth dependence of the space radiation. A silicon wafer in contact with PNTDs was also included for measurement of the high LET fluences of secondary particles originating in the silicon. The secondary radiation may contribute substantially to electronic microcircuit failures in space.

The radiation detectors in this experiment allow a number of measurements to be made. At present only the TLDs have been read out. Absorbed doses as functions of shielding thickness (due to the Al canister and the composition of the detectors only) are given. The remaining measurements will be reported at a later date.

## EXPERIMENT

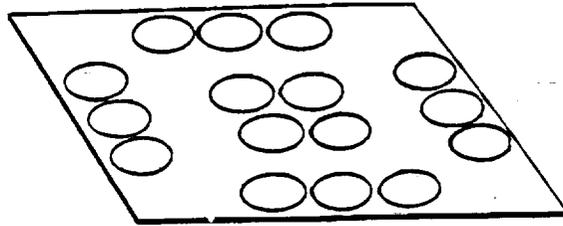
The EURECA satellite was launched with the STS-46 mission at 8:57 a.m. CDT on July 31, 1992 and returned with the STS-57 mission at 7:52 a.m. CDT on July 1, 1993, for a total duration in space of 335 days. The orbit was 426 km in altitude with an inclination of 28.5°. The flight canister was mounted within the Exobiology Radiation Assembly (discussed below) with open space through an aperture to one side of the canister.

The complement of detectors included in the experiment were a TLD plate, nearest the top of the canister, followed by the Trackoscope and the thick detector stack. The layout is shown in Fig. 1. The TLD plate was acrylic, with 16 holes for placement of TLDs; 4 around the center of the plate and 3 at each side.

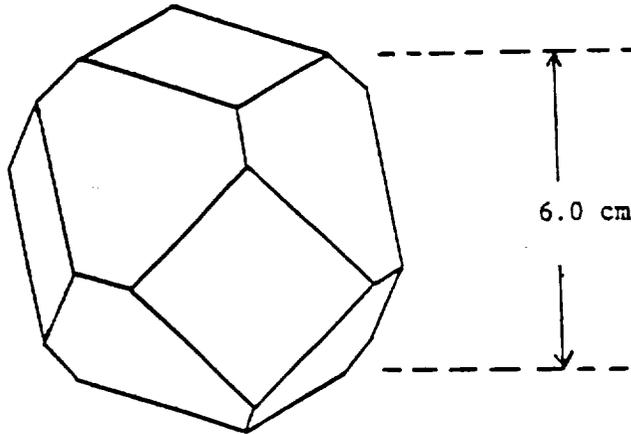
The Trackoscope base was a truncated cube of acrylic with 14 faces (7 parallel pairs with 6-cm separations). PNTD stacks of 2.86 cm diameter and 0.45 cm thickness were attached to the faces. This arrangement compensates for the directional response of the PNTDs.

The thick detector stack contains layers of TLDs, PNTDs and aluminum, interspersed, and also a silicon wafer, held in place within a polyethylene sheet, and a TRND layer. The thick stack allows a measurement of shielding dependence of absorbed dose and heavy particle LET spectra. A comparison of the LET spectrum

TLD-1  
LAYER



TRACKOSCOPE  
BASE



DETECTOR  
STACK

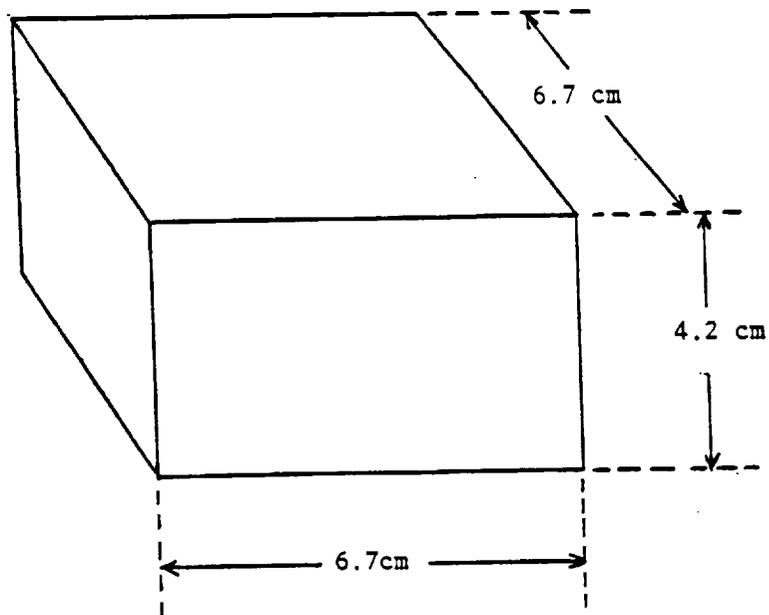


Fig.1 Detector components for EURECA radiation experiment. The Trackoscope base is a truncated cube with 7 pairs of parallel faces. PNTD sub-stacks (2.86 cm diam. x 0.25 cm thick) were placed on each of the 14 faces. The detector stack contained 6 additional TLD layers at various depths.

adjacent to the Si wafer with that in the near vicinity will yield information about secondary particle production within the wafer. The low energy neutron fluence, to be measured with the TRNDs, is of interest from the standpoint of dosimetry and as a test for the radiation modeling codes. The contents of the detector array are given in Table 1.

There were seven TLD plates included in the detector array with 16 TLD-700 chips (0.635 x 0.635 x 0.089) in each. After the mission, the TLDs were read out, with controls and  $^{137}\text{Cs}$   $\gamma$ -ray calibration chips, in a Harshaw Model 4000 reader. A pre-readout annealing cycle was used (120°C for 10 sec) to eliminate the low temperature LiF glow peak from the response. A low temperature fading study has shown that this eliminates the need for a fading correction for the EURECA time period. The flight and calibration TLDs were recalibrated together afterward to improve response accuracy.

### MEASUREMENTS

The 16 TLD doses in each plate have been averaged into 5 groups: center, left, back, right, front. The measurements are given in Table 2 and Fig. 2. The direction of maximum intensity of radiation is seen to be diagonally through the right side and top of the canister. The minimum and maximum doses are 18.8 and 38.9 cGy.

### DISCUSSION

The direction of maximum radiation intensity in the flight canister should correspond to the direction of minimum external shielding. The positions of the Biostack flight canisters, one of which was occupied by the detectors, is shown in Fig. 3 relative to the Exobiology Radiation Assembly. It can be seen that one side of the canister is unshielded to space. Also the top of the canister is set back from the side of the assembly so that the top has a significant solid angle open to space. It is also probable that the top of the canister receives a significant fraction of dose through the side of the assembly. This corresponds well to the expected external shielding as projected from the dose distribution.

An accurate solid angle distribution of external shielding about the detector canister will allow the dose measurements to be compared with calculations based on environmental radiation models. A comparison with dose rates measured on LDEF (Frank et al., 1992) is given in Fig. 4. For equivalent shielding, the EURECA dose rates are less than those at all LDEF locations. This is qualitatively consistent with the difference in the external shielding. The LDEF flight canisters (P0006 and A0015) were open to space over an approximately  $2\pi$  solid angle, while the open solid angle on EURECA was much smaller. Also the different altitudes of

EURECA and LDEF contributed to higher LDEF doses. EURECA was launched from STS-46 with a Shuttle altitude of 426 km. LDEF was launched from STS-41C with the Shuttle at an altitude of 478 km. The LDEF altitude decayed, but a higher average trapped proton flux can be expected for this mission. At greater shielding depths the differences are smaller and the EURECA dose rates may be approximately equal to those at the LDEF leading edge.

#### REFERENCES

Frank A.L., Benton E.V., Armstrong T.W. and Colborn B.L. (1992) Absorbed dose measurements and predictions on LDEF. Second Post-Retrieval LDEF Symposium, San Diego, CA, June 1992. NASA Conference Publication 3194, Part 1, Washington DC, pp. 163-170.

TABLE 1. EURECA DETECTOR ASSEMBLY

<u>Material</u>	<u>Layers</u>	<u>Layer Thickness (cm)</u>	<u>Label</u>
TLD (Acrylic)	1	0.165	TLD #1
Trackoscope		6.92	ET-1 -- ET-14
Lexan	1	0.025	
TLD (Acrylic)	1	0.165	TLD #2
CR-39 (+PC)*	4	0.060	EUR-1 -- EUR-4
Al	1	0.159	
TLD (Acrylic)	1	0.165	TLD #3
CR-39 (+PC)	4	0.060	EUR-5 -- EUR-8
Al	1	0.159	
TLD (Acrylic)	1	0.165	TLD #4
CR-39 (+PC)	4	0.060	EUR-9 -- EUR-12
Al	1	0.318	
TLD (Acrylic)	1	0.165	TLD #5
CR-39 (+PC)	4	0.060	EUR-13 -- EUR-16
Al	1	0.318	
TLD (Acrylic)	1	0.165	TLD #6
CR-39 (+PC)	4	0.060	EUR-17 -- EUR-20
Si/Polyethylene	1	0.015	
CR-39	1	0.060	EUR-21
Al	1	0.159	
TLD (Acrylic)	1	0.165	TLD #7
<sup>6</sup> LiF/CR-39 (Acrylic)	1	0.350	EUR-TRND
Lexan	1	0.025	

\*8 $\mu$ m-thick polycarbonate film was placed between adjacent layers of CR-39

TABLE 2

## TLD Absorbed Doses Measured on EURECA

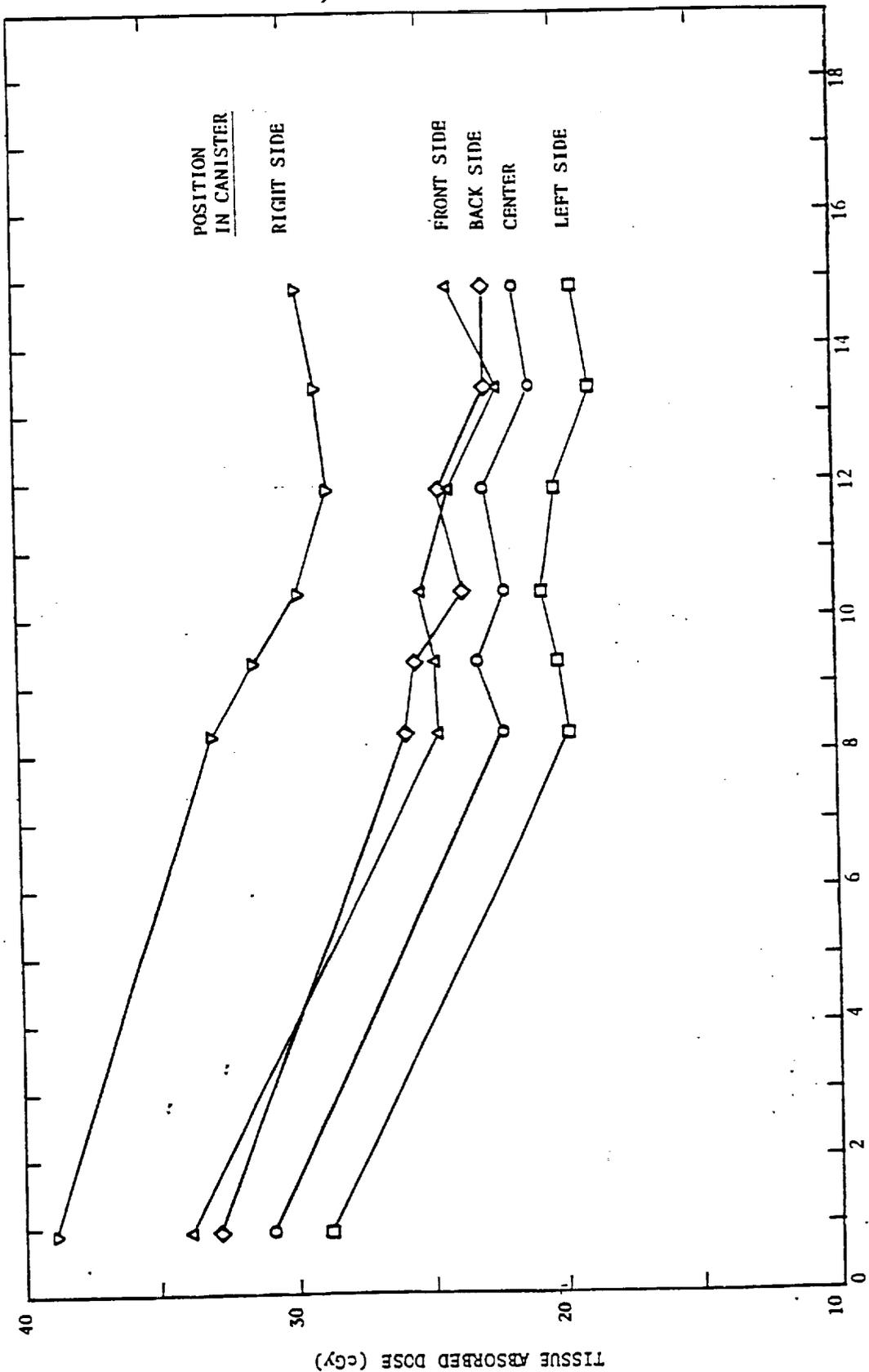
<u>TLD PLATE</u>	<u>Absorbed Dose (cGy)</u>					<u>Shielding Thickness Al Equiv.</u>
	<u>Center</u>	<u>Front</u>	<u>Left</u>	<u>Back</u>	<u>Right</u>	<u>(g/cm<sup>2</sup>)</u>
1	30.9±0.9	33.9±1.0	28.8±0.9	32.8±1.0	38.9±1.2	0.92
2	22.3±0.7	24.6±0.7	19.7±0.6	25.8±0.8	32.9±1.0	8.30
3	23.2±0.7	24.7±0.7	20.1±0.6	25.4±0.8	31.3±0.9	9.36
4	22.2±0.7	25.2±0.8	20.7±0.6	23.7±0.7	29.7±0.9	10.4
5	22.9±0.7	24.1±0.7	20.1±0.6	24.5±0.7	28.6±0.9	11.9
6	21.1±0.6	22.3±0.7	18.8±0.6	22.8±0.7	29.0±0.9	13.4
7	21.7±0.7	24.1±0.7	19.4±0.6	22.8±0.7	29.6±0.9	14.9

The uncertainty given is standard deviation,  $\sigma$ .

The shielding given is the averaged vertical shielding to the top of the detector array and includes the top of the flight canister. Shielding external to the canister is not given.

Minimum shielding of the side TLDs through the sides of the canister was 1.13 g/cm<sup>2</sup>, Al equivalent.

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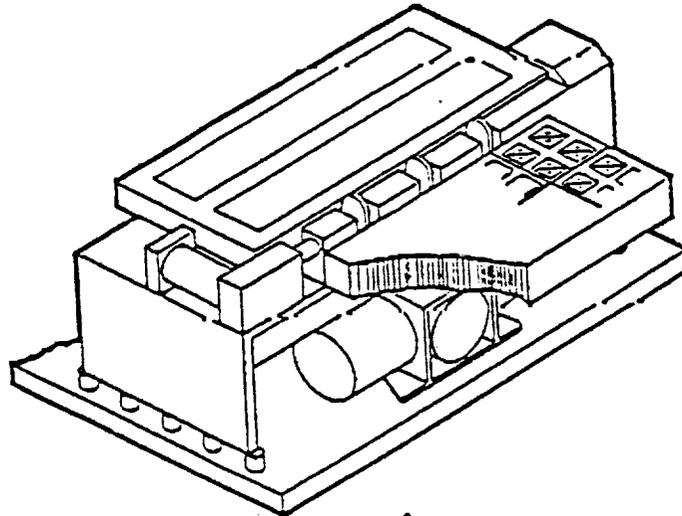


VERTICAL SHIELDING - Al EQUIVALENT (g/cm²)

Fig. 2. TLD-700 dose as a function of shielding thickness of the IDFF A0015 canister and contents. Shielding is measured vertically to the top of the canister. Minimum external shielding is to the right side of the canister.

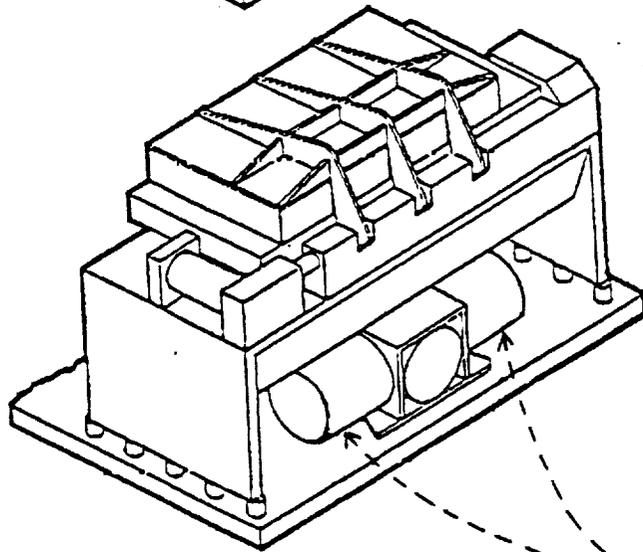
# EURECA EXO BIOLOGY RADIATION ASSEMBLY

WITH TRAY  
DEPLOYED



↑  
DIRECTION  
OF SUN

WITH TRAY  
STOWED



FLIGHT  
CANISTERS

Fig. 3. The positions of flight canisters relative to the exobiology radiation assembly on the EURECA satellite

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TISSUE ABSORBED DOSE RATE (mGy d<sup>-1</sup>)

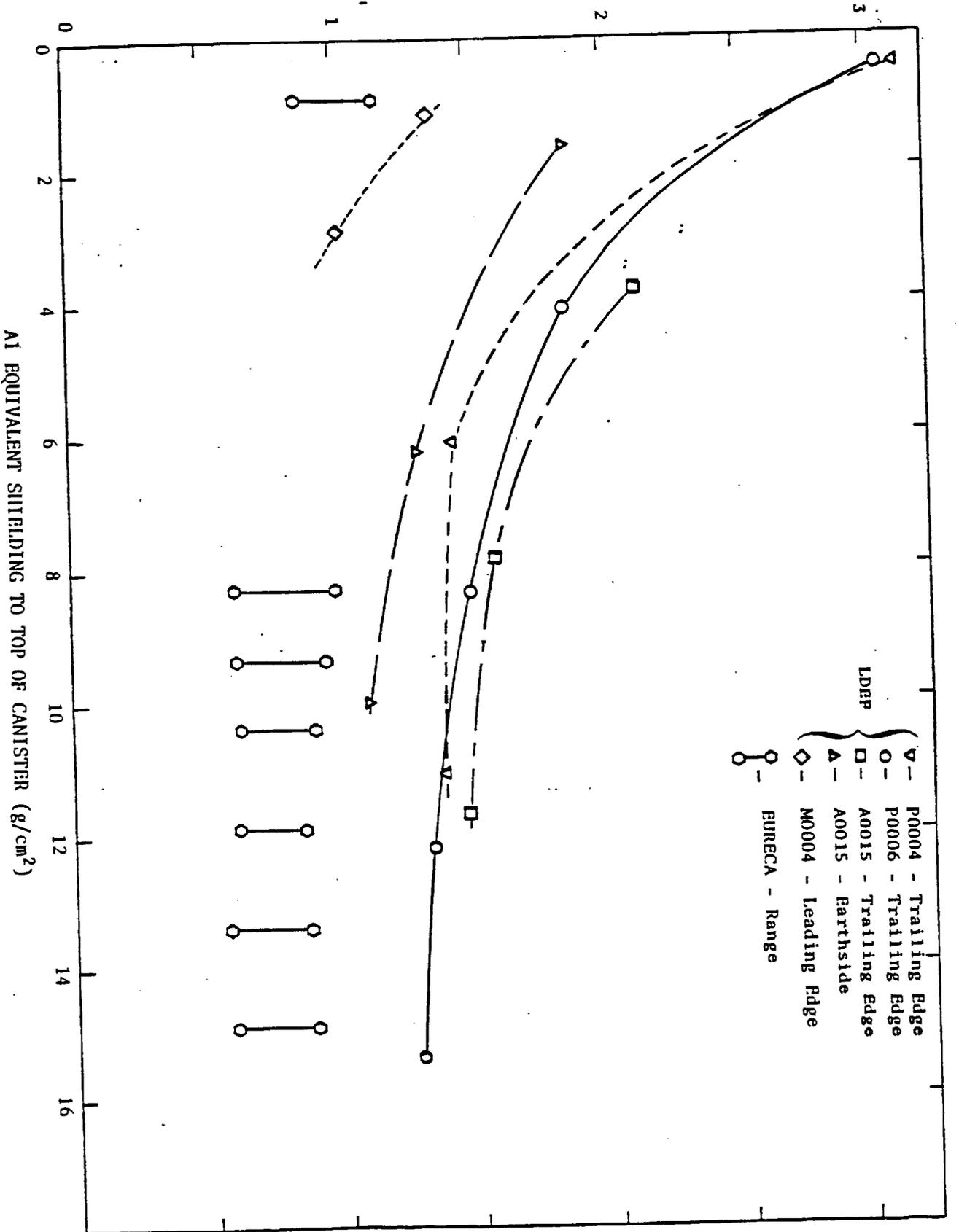


Fig. 4. Comparison of LDEF and EURECA TID-700 dose rates as functions of shielding from the flight canisters and their contents (also thermal blankets on LDEF).

